

## Mitigating Combustible Dust Hazards Associated with Dust Collectors

*Dust collection systems have a high risk of explosions, which is why they are addressed by OSHA's National Emphasis Program for combustible dust. How do you know if your dust collection system complies? What do you do if it doesn't? How do you minimize risks for your employees and facility?*

*This white paper reviews the OSHA National Emphasis Program for combustible dust, the NFPA standards that address how to prevent or limit explosion hazards, how to identify these hazards, the need for dust testing and a dust hazard analysis, the types of equipment used for explosion protection, and dust collector housekeeping basics.*



# Mitigating Dust Collector Combustible Dust Hazards

Combustible dust explosions can occur without warning in many manufacturing areas, but one of the most common locations is the dust collection system. That's because dust collectors can hold a lot of suspended combustible dust in one confined space. For this reason dust collectors must meet the National Fire Protection Association (NFPA) standards and codes that protect buildings against fire and explosion risks. Today, the Occupational Safety & Health Administration (OSHA) is applying these standards with increasing vigilance.

So how do you know if your dust collection system complies with the latest regulations? What do you do if it doesn't? Are your employees at risk? How do you identify these hazards and put systems in place to mitigate them?

This white paper reviews the current status of the OSHA National Emphasis Program for combustible dust, the NFPA standards that address how to prevent or limit explosion hazards, how to identify these hazards, how to conduct a dust hazards analysis (DHA) and the types of equipment used to eliminate or control explosion hazards.

## An Ongoing History of Tragic Dust Explosions

Combustible dust explosions over the past decade in U.S. plants are blamed for well over 100 fatalities and hundreds more injuries. Here are just a few samples:

- On Dec. 8, 2017, an outdoor dust collector exploded at the UTC Aerospace Systems plant in Vergennes, VT, injuring four workers inside the facility.
- On May 31, 2017, an explosion killed five workers and injured 12 others at Didion Milling, Inc. in Cambria, Wisconsin. The U.S. Department of Labor's Occupational Safety and Health Administration (OSHA) has proposed \$1,837,861 in fines because they believe the explosion likely resulted from Didion's failures to prevent the accumulation of highly combustible grain dust throughout the facility.
- In January 2003, an explosion at the West Pharmaceutical facility in Kinston, North Carolina killed six workers and injured 38 others, including two firefighters. The culprit: inadequate control of dust hazards at the plant. Only a month later, in February 2003, another explosion and fire damaged the CTA Acoustics manufacturing plant in Corbin, Kentucky, fatally injuring seven workers. Investigators found that resin dust, accumulated in a production area, was likely ignited by flames from a malfunctioning oven, triggering the explosion.
- In February 2008, the most famous combustible dust explosion in the past decade occurred at the Imperial Sugar Company's Port Wentworth, Georgia refinery. It was the one responsible for refocusing the national spotlight on this issue. A dust cloud explosion triggered a fatal blast and fire that killed 13 workers and injured 42 others, generating a storm of media attention and government scrutiny.



*Explosion at Veolia Environmental Services in Sarnia, Canada*



*Dust Collector After Explosion*

These are by no means the only accident related incidents, but these are the most recent and deadliest to be investigated. In 2006, after investigating three combustible dust-related incidents over a two-year period, the Chemical Safety Board (CSB) conducted an in-depth study that identified 281 explosions caused by ignited combustible dust. These explosions resulted in 199 fatalities and 718 injuries. Since that time, the CSB has conducted four additional investigations into dust-related incidents, and the agency's Office of Incident Screening and Selection continues to identify serious dust-related incidents on a regular basis.

Sadly, experts believe these accidents could have been prevented if the companies involved had followed best practices for fire and explosion protection such as the methodologies described in this white paper.

## The Dust Explosion Pentagon

To understand combustible dust risks, take a look at the “dust explosion pentagon” (Figure 1). All five elements need to be present in an industrial facility at the same time to cause an incident (1) combustible dust; (2) an ignition source; (3) oxygen in the air; (4) dispersion of the dust in sufficient concentration to be explosive; and (5) containment of the dust cloud within a confined or semi-confined vessel or area.

A closed vessel like a dust collector can create the perfect scenario for an explosion if an ignition source enters the collector. When a pulse cleaning event occurs, a suspended cloud of combustible dust is present in high concentration within the collector. An ignition source completes the five elements of a dust explosion and initiates the explosion.

Though some incidents involve a single explosion, it is more common for a series of deflagrations to occur. The initial explosion can dislodge ignitable dust hidden on overhead surfaces or other areas over a large area and trigger secondary explosions that can be ignited from the initial explosion or from other ignition sources. It is these secondary explosions that have historically caused the majority of injuries and damage to property.

An incident like this could occur at your facility even if there has never been a problem before. Most of the events above were the first to occur, and happened without warning. The hazard level can change from day to day and even from moment to moment – whether due to the introduction of a new process, a change in housekeeping, or a static electricity discharge caused by improper grounding. It takes ongoing vigilance and management of change to identify conditions in your plant that might cause a potential safety problem.

## Regulatory Agencies and Non-Compliance Penalties

There are three key entities involved in combustible dust issues, each with its own particular area of responsibility:

**NFPA:** The NFPA sets safety standards, amending and updating them on a regular basis. As noted, when it comes to combustible dust, there are several different documents that come into play, as summarized in the section directly below. Together these standards add up to total protection to prevent an explosion, vent it safely, and/or ensure that it will not travel back inside a building. Most insurance agencies and local fire codes state that NFPA standards shall be followed as code.



*Figure 1: Dust explosion pentagon shows the elements that must be present for a combustible dust explosion to occur.*

Exceptions would be where the authority having jurisdiction (AHJ), such as Factory Mutual, specifies an alternative safety approach which might be even more stringent.

**OSHA:** It is OSHA's role, together with local authorities, to enforce the standards published by NFPA. In the aftermath of the Imperial Sugar Company explosion in 2008, OSHA reissued its 2007 Combustible Dust National Emphasis Program (NEP) outlining policies and procedures for inspecting workplaces that create or handle combustible dusts.

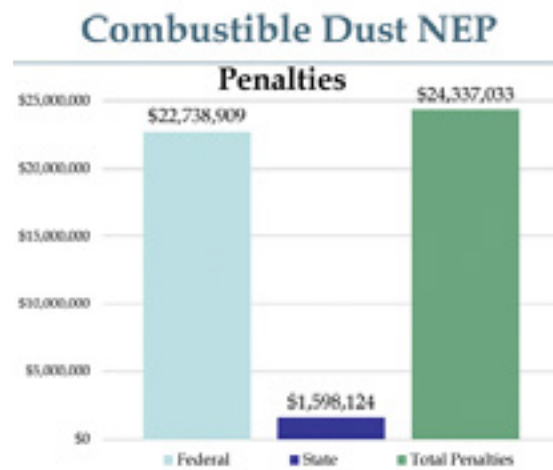
After 2007, OSHA revised its NEP and defined dusts to include metal dusts like aluminum and magnesium, wood dusts, coal and other carbon dusts, plastic dusts, bio-solids, certain textile materials and organic dusts like sugar, flour, paper, soap, and dried blood. When it was published, this change increased inspections in 64 focus industries with more frequent and serious dust incidents.

OSHA's Combustible Dust NEP lists 18 different standards that can be used to inspect and cite workplaces that create or handle combustible dusts. These standards cover everything from ventilation and electrical systems to housekeeping regimens. You can even be cited when inspectors find hazards not addressed by the NEP. In those cases OSHA turns to the General Duty Clause of the Occupational Health and Safety Act of 1970. This clause mandates that employers provide a workplace free from recognized hazards that are likely to cause death or serious physical harm. So, if combustible dust hazards are present at your facility and not properly mitigated, the inspector can assume risk and serve you with a citation.

**U.S. Chemical Safety Board (CSB):** The CSB is an independent federal agency responsible for investigating industrial chemical accidents. Staff members include chemical and mechanical engineers, safety experts, and other specialists with chemical industry and/or investigative experience. The CSB conducts thorough investigations of explosions like the ones mentioned above – sifting through evidence to determine root causes and then publishing findings and recommendations. The CSB has a wealth of information on their web site ([www.csb.gov](http://www.csb.gov)), including educational videos depicting how combustible dust explosions occur.

The CSB has become an outspoken advocate of the need for more stringent combustible dust regulations and enforcement. On February 7, 2012, the fourth anniversary of the Imperial Sugar explosion, the chairman of the CSB issued a statement in which he applauded the progress made to date in dealing with combustible dust issues. He noted, however: "Completing a comprehensive OSHA dust standard is the major piece of unfinished business from the Imperial Sugar tragedy...We believe such a standard is necessary to reduce or eliminate hazards from fires and explosions from a wide variety of combustible powders and dust." The CSB has also recommended that the International Code Council, which sets safety standards that are often adopted by state and local governments, revise its standards to require mandatory compliance with the detailed requirements of the various NFPA standards relating to combustible dust.

**United States Congress:** Some members of Congress are also advocating faster action by OSHA to implement a combustible dust standard. In February 2011, Representative George Miller of California, together with cosponsors John Barrow of Georgia and Lynn Woolsey of California, reintroduced a bill titled "The Worker Protection against Combustible Dust Explosions and Fires Act" (H.R. 522). If enacted, it would require OSHA to issue an interim standard within one year of passage and the Secretary of Labor to issue a proposed rule 18 months later, with a final rule due within another three years. At the



*Penalty graph shows fines imposed from commencement of the OSHA Combustible Dust National Emphasis Program (NEP) in 2008 until October 2011.*

*(Image courtesy of [www.oshalawupdate.com](http://www.oshalawupdate.com))*

time of this writing, there has been no vote on H.R. 522. A similar bill passed the House in April 2008 but never went to the Senate.

## Relevant NFPA Standards

In trying to sort through the list of combustible dust standards, a good starting point for every facility engineer or manager is NFPA 654, the Standard for the Prevention of Fire and Dust Explosions from the Manufacturing, Processing and Handling of Combustible Particulate Solids. Simply stated, NFPA 654 is an all-encompassing standard on how to design a safe dust collection system. It is regarded as the guiding dust document and the most general on the topic, and it will lead you to other relevant documents.

Depending on the nature and severity of the hazard, NFPA 654 will guide you to the appropriate standard(s) for explosion venting and/or explosion prevention, as follows:

**NFPA 68** – Standard on Explosion Protection by Deflagration Venting: This document focuses on explosion venting – i.e., on devices and systems that vent combustion gases and pressures resulting from a deflagration within an enclosure, for the purpose of minimizing structural and mechanical damage. The current edition, published in 2007, contains much more stringent requirements than past editions, essentially elevating it from a guideline to a standard.

**NFPA 69** – Standard on Explosion Prevention Systems: This standard covers explosion protection of dust collectors when venting is not possible. It covers the following methods for prevention of deflagration explosions: control of oxidant concentration, control of combustible concentration, explosion suppression, deflagration pressure containment, and spark extinguishing systems.

In addition to the above, the following NFPA standards may be applicable to your situation: 664 for wood processing facilities, 484 for combustible metals, 61 for agricultural and food processing facilities, 91 for air conveying of vapors, gases, mists and particulate solids, 655 for sulfur fires and explosions, 13 for sprinkler systems and 17 for static electricity.

### Using Performance-Based Codes

In 1995, the NFPA created a Performance-Based (PB) Support Team to assist NFPA Technical Committees with the transition to performance-based documents. Since that time, the NFPA has been incorporating performance-based options into its updated standards. Using the newer performance-based codes, solutions no longer have to follow NFPA standards to the letter if the variance is backed by full-scale, real-world destructive test data provided by a third party. The NFPA 654 general dust document first adopted this concept in 2006, with the other more specific combustible dust standards following suit since that time.

Performance-based provisions state specific life safety objectives and define approved methods to demonstrate that your design meets these objectives. They give equipment manufacturers and plant engineers greater flexibility by allowing methods to quantify equivalencies to existing prescriptive-based codes or standards, as long as the proposed solution demonstrates compliance.



*Toner dust explosion in the UK.*

A performance-based design procedure includes the following steps:

- |  |   |
|--|---|
| (1) Establish safety goals                                     | (6) Select calculation methods (e.g. computer models) |
| (2) Evaluate all aspects of the facility with regard to safety | (7) Develop a proposed solution                       |
| (3) Identify potential hazards                                 | (8) Assess the solution                               |
| (4) Define appropriate hazard scenarios                        | (9) Obtain approval                                   |
| (5) Establish performance objectives and criteria              |   |

## Test Your Dust and Conduct a Dust Hazard Analysis

How do you know if your dust is combustible? OSHA assumes that it is unless you have the test results to prove that your dust has a 0 Kst value. If your dust is common – like flour, sugar, etc. – and your particle size and moisture content are the same, you can use documented historical data from other tests. That data must be documented and kept on file at your facility.

Figure 2 shows Kst values of these common dusts.

Other dusts must be tested through a private lab or OSHA, and you must keep the test data on file. Many commercial test labs offer a low-cost test to establish whether a dust sample is combustible. If the test is positive, then the explosive index (Kst) and the maximum pressure rise (Pmax) of the dust should be determined by ASTM E 1226-10, Standard Test Method for Explosibility of Dust Clouds. The fact is, any dust above 0 Kst is now considered to be explosive, and the majority of dusts fall into this category.

If tests show that your dust has a Kst value greater than zero, you have combustible dust and NFPA 652 required you to complete a Dust Hazard Analysis (DHA) by September, 2018. A DHA allows you to determine potential combustion risks for dusts produced or handled in your facility. It is needed to assess risk and determine the required level of fire and explosion protection. The analysis can be conducted internally or by an independent consultant, but either way the authority having jurisdiction will ultimately review and approve the findings.

Your dust collection equipment supplier will need the Kst and Pmax values in order to correctly size explosion venting or suppression systems. Failure to provide this information will increase your costs, since the supplier will have to use worst-case estimates of the Kst and Pmax values or may even refuse to provide the equipment. The liability to the manufacturer and to the equipment purchaser is too high to ignore the life safety objectives.

Kst Values of Common Dusts		
Common Dusts	Micron	Kst Value
Activated Carbon	18	44
Aluminum Grit	41	100
Aluminum Powder	22	400
Asphalt	29	117
Barley Grain Dust	51	240
Brown Coal	41	123
Charcoal	29	117
Cotton	44	24
Magnesium	28	508
Methyl Cellulose	37	209
Milk Powder	165	90
Paper Tissue Dust	54	52
Pectin	59	162
Polyurethane	3	156
Rice Starch	18	190
Silicon	10	126
Soap	65	111
Soy Bean Flour	20	110
Sulphur	20	151
Tobacco	49	12
Toner	23	145
Wood Dust	43	102

Figure 2: Kst values of common dusts



If OSHA determines that even a very low Kst dust is present in a facility with no explosion protection in place, a citation will result. This is one of the biggest changes to occur with the reintroduction of the OSHA NEP in 2008.

## Technologies for Explosion Protection

Many different types of devices and systems are used to comply with NFPA standards for the explosion protection of dust collection systems. They fall into two general categories: passive and active.

The goal of a passive system is to control an explosion to keep employees safe and minimize plant and equipment damage. An active system involves much more costly technology and typically requires recertification every three months. Whichever system you install, make certain to use certified explosion protection devices.

### PASSIVE DEVICES

#### Explosion venting

This type of venting is designed to be the “weak” link of the dust collector. When the inside of the collector reaches a predetermined pressure, the explosion vent opens, allowing the excess pressure and flame front to exit to a safe area. It is designed to minimize damage to the collector and prevent it from blowing up in the event of a deflagration (Figure 3).

#### Flameless venting

Designed to be installed over a standard explosion vent, a flameless vent extinguishes the flame exiting the vented area, preventing it from exiting the device. With flameless venting, conventional venting can be placed indoors as long as there is a designated safe zone (Figure 4).

#### Passive float valve

A passive float valve is designed to be installed in the outlet ducting of a dust collector. A mechanical barrier prevents flames from propagating further upstream through the ducting. The mechanical barrier reacts within milliseconds and is closed by the pressure of the explosion.



Figure 3: Explosion venting device



Figure 4: Flameless venting device



These dust collectors are equipped with passive and active controls that include an explosion vent and ducting, as well as a chemical isolation system mounted on the inlet duct.

### **Back draft damper**

A mechanical back draft damper is positioned in the inlet ducting downstream from the dust collector. This mechanical barrier is held open by the process air and is slammed shut by the explosion's pressure force, preventing flames from propagating further upstream through the ducting.

### **Flame front diverters**

These devices divert the flame front to atmosphere and away from the downstream piping. Typically, flame front diverters are used between two different dust collectors equipped with their own explosion protection systems. The flame front diverter is used to eliminate "flame jet ignition" between the two.



*This dust collector is equipped with an explosion vent with vertical upblast deflector plate. Other safety features include a sprinkler system and filters with special carbon-impregnated media for static dissipation.*

## **ACTIVE DEVICES**

### **Chemical isolation**

Reacting within milliseconds of detecting an explosion, this system can be installed in inlet or outlet ducting. Typical components include explosion pressure detector(s), flame detector, chemical agent, and a control panel. It creates a chemical barrier that suppresses the explosion within the ducting and reduces the propagation of flame through the ducting.

### **Chemical suppression**

Chemical isolation is used to detect and suppress explosions within the ducting and protect the dust collector. It is often used when it is not possible to safely vent an explosion or where the dust is harmful or toxic. The system detects an explosion hazard within milliseconds and releases a chemical agent to extinguish the flame before an explosion can occur.

### **Fast acting valve**

Designed to close within milliseconds of detecting an explosion, the valve installs in either inlet and/or outlet ducting. It creates a mechanical barrier within the ducting that effectively isolates pressure and flame fronts from either direction, preventing them from propagating further through the process.

## **The Dangers of Non-Compliant Devices**

As an example, sometimes products such as back draft dampers may be reverse-engineered by suppliers that do not have any expertise in explosion protection or have chosen not to perform the required testing to satisfy the standards and/or the performance-based provisions. No testing exists to prove that the device will comply with current standards.

If an OSHA inspector finds this situation in the field, the plant will have to replace the device and may be subject to a fine. Worse yet, if a combustible dust problem should occur, there is no guarantee that the device will perform as expected.

It is also worth noting, there is no such thing as an "NFPA-approved" device. A supplier may correctly state that a device "carries CE and ATEX certifications" and/or is "manufactured in accordance with NFPA standards" – but test data must be available to support these claims. Such a device might cost more than its non-compliant counterpart, but in the long run it can save money, headaches, and even lives.



### High-speed abort gate

The gate is installed in a dust collector's inlet or outlet ducting. It diverts possible ignition hazards from entering the collector, preventing a possible explosion from occurring. It also prevents flame and burning debris from entering the facility through the return air system diverting process air to a safe location. Abort gates are activated by a spark detection system located far enough upstream to allow time for the gate to activate.

## ADDITIONAL EXPLOSION PROTECTION TECHNOLOGIES

When planning explosion protection, don't overlook additional devices and materials that can help reduce fire risk within the dust collection system. For spark-generating applications, a range of features and technologies are available, from flame-retardant and carbon conductive filter media to spark arrestors in the form of drop-out boxes, perforated screens or cyclone device installed at the collector inlet. Fire sprinkler systems may also be required with some installations and can be coupled with smoke detection or other pressure detection systems.

A dust collector that uses vertically-mounted filter cartridges can also reduce fire and explosion risks (Figure 5). With horizontally-mounted cartridges, dust becomes trapped in the pleats in the upper third of the filters (Figure 6). This dust will become dispersed during a deflagration providing unnecessary excessive amounts of extra fuel for the event. Horizontal cartridges are also exposed to all of the dust entering the collector, coarse and fine. This leads to premature failure from abrasion and leaks. These leaks can go unnoticed for quite some time while fine combustible dust is blown into your facility. Vertically-mounted filters use baffle systems to segregate much of the dust into the hopper, which reduces the load on the filters and helps eliminate these problems.

### Demonstrating Compliance with Destructive Testing Data

The NFPA uses relatively conservative textbook calculations in its standards for explosion protection equipment, and justifiably so. However, as noted earlier on page 5 (see performance-based codes), the NFPA also allows real-world destructive test data to be used in place of its own standard calculations, provided the dust collection supplier can provide adequate data to prove that the collection system is designed to meet a specific set of criteria for a given situation. The use of real-world destructive test data is thus a permissible and sometimes overlooked strategy.



Figure 5: Vertically-mounted dust collector filters



Figure 6: Horizontally-mounted dust collector filters

An example is actual explosion testing of a dust collector to show that it will stand up to anticipated pressure conditions, instead of using the reduced pressure calculations in NFPA 68. By combining field testing and full-scale dust collection laboratory test apparatus to prove certain assumptions, this approach might allow you to install longer duct lengths in a given application; to use a single explosion vent where multiple vents might otherwise have been needed; or even to use explosion venting in place of a more costly chemical suppression system. Find out if your dust collection supplier can provide real-world test data to assist in a strategy that may help you to avoid over-engineering and save on equipment costs without compromising safety.

## Selecting Dust Collection Systems Based on Life-Cycle Cost

Every plant engineer and manager is acquainted with the benefits of basing purchasing decisions on life-cycle cost – sometimes called “total cost of ownership” – over choosing equipment with the lowest price tag. A dust collector is no exception. A well-designed dust collection system can pay for itself rapidly in energy and maintenance savings, costing far less to operate than a unit with a low initial price.

A high-quality, heavy duty collector can also offer a less obvious advantage in the event of a combustible dust problem. As documented both in full-scale testing and field experience, in the event that a dust explosion occurs in the collector, a “bargain” model will more than likely require total replacement. A collector made of thicker-gauge metal with higher vessel strength, however, will survive an explosion and can often continue in service with only the explosion vent and filter cartridges needing to be replaced.

## Dust Collector Housekeeping Basics

In an October 2011 update on the Combustible Dust NEP, OSHA reported that one common violation encountered during inspections involved “hazardous levels of dust accumulation in the workplaces due to poor housekeeping practices.”

It is important to regularly inspect the collector, connected duct work, and the surrounding safety zone. You should inspect all of these according to each manufacturer’s installation and operation manual. Also, you should remove any dust build-up within the system, duct work, or safety zone as often as possible.



*At the startup of a staged explosion, explosive dust is injected into the dust collector to create a flammable cloud.*



*About 5 milliseconds later, the dust ignites and the vent opens.*



*The flame is almost immediately diverted away from the dust collector to a safe area.*



*The smoke quickly clears. The whole event took about 150 milliseconds.*

When it comes to the dust collector, a simple but important housekeeping requirement is to change filters properly. They should be changed either:

- When airflow through the system reaches a differential pressure limit as prescribed by the manufacturer.
- When the pressure drop across the collector is negatively affecting the ability of the dust collection system to capture the dust, thus allowing it to escape into the facility.

Some long-life cartridge filters available today can operate for two years or even longer between change-outs; but for heavy dust-loading applications, filter replacement might be considerably more frequent.

It is also important not to store dust in the dust collector's hopper. The hopper should be equipped with a device that discharges the dust into a separate drum or storage container after it is pulsed off the filters during the cleaning process. Equally important, this storage container must be emptied regularly, or dust can back up into the hopper. Dust left sitting in a hopper creates a potential fire or explosion risk, and may also affect performance of the dust collection system. This will lead to loss of airflow and reduce conveying velocities. Dust will build up in the ducting and in the process hoods.

## Conclusion

NFPA 652 required all facilities with combustible dust and a dust collection system to perform a DHA by September 2018 in order to identify, manage, and communicate fire and explosion hazards. Not everyone agrees on the best way to tackle combustible dust issues. Some concur with the CSB position that OSHA needs to accelerate efforts to produce and enforce its own standard, citing a long-standing precedent with the grain industry. According to OSHA, "The lessons learned in the grain industry can be applied to other industries producing, generating, or using combustible dust."

Others argue that more stringent and perhaps consolidated dust standards from the NFPA, diligently enforced by OSHA and local authorities, would be preferable to a separate OSHA standard. What everyone does seem to acknowledge is that more drastic action is necessary to prevent combustible dust tragedies from continuing to occur.

Until such action is mandated, a certain degree of self-regulation is called for. Managers of industrial facilities can choose to be part of the problem or part of the solution. By following the guidelines in this article, and securing the help of engineering consultants and equipment suppliers with a proven track record in combustible dust applications and performance-based solutions, you can minimize risk factors and maximize combustible dust safety in your facility.

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*This heavy duty dust collector with explosion vent is designed to survive a combustible dust explosion with minimal damage.*

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